OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
ANALYSIS/MODEL COVER SHEET
Complete Only Applicable Items

1. QA: QA

2. ☒ Analysis — Check all that apply

Type of Analysis
- ☐ Engineering
- ☒ Performance Assessment
- ☐ Scientific

Intended Use of Analysis
- ☐ Input to Calculation
- ☒ Input to another Analysis or Model
- ☐ Input to Technical Document
- ☐ Input to other Technical Products

Describe use:

Parameter values defined in this report will be used to calculate biosphere dose conversion factors.

3. ☐ Model — Check all that apply

Type of Model
- ☐ Conceptual Model
- ☐ Abstraction Model
- ☐ Mathematical Model
- ☐ System Model
- ☐ Process Model

Intended Use of Model
- ☐ Input to Calculation
- ☐ Input to another Model or Analysis
- ☐ Input to Technical Document
- ☐ Input to other Technical Products

Describe use:

4. Title:

Input Parameter Values for External and Inhalation Radiation Exposure Analysis

5. Document Identifier (including Rev. No. and Change No., if applicable):

ANL-MGR-MD-000001, REV 00, ICN 1

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OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
ANALYSIS/MODEL REVISION RECORD
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2. Analysis or Model Title:

Input Parameter Values for External and Inhalation Radiation Exposure Analysis

3. Document Identifier (including Rev. No. and Change No., if applicable):

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4. Revision/Change No.	5. Description of Revision/Change
REV 0, ICN 1	Changed verification status of climate data (Table 1 and DIRS) and added justification for use of Q-VL2 data (p. 7); added data tracking numbers for data accepted since release of REV 00 (Table 1; pp. 9, 10, 17, 19, 21; DIRS); used modified crop coefficients for turf grass, which resulted in diffferent values for irrigation rate (Tables 1, 3, 4 and pp. 10, 19); modified justification for selecting climate and air quality data from site 9 (pp. 7, 8, 9); added statement that ingested dust is considered in ingestion pathway (p. 7); replaced reference to unfinished AMR with reference to Census Bureau data (pp. 6, 9, 10, 11, 12, 16); modified assumption 2 in Section 5.5 to address DIR associated with CAR LVMO-99-C-001 (p. 13); added required statement about tracking input status (p. 22); used electronic DIRS; and modified references to match electronic DIRS (pp. 22-25).

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TABLES

1. PURPOSE

The purpose of this analysis and model report (AMR) is to select and justify values for six input parameters used by the computer code GENII-S (Leigh et al. 1993). The GENII-S code is being used to estimate radionuclide-specific biosphere dose conversion factors. The Civilian Radioactive Waste Management System Management and Operating Contractor (CRWMS M&O) Performance Assessment Organization will use the biosphere dose conversion factors to calculate potential radiation doses to a hypothetical human receptor group as part of the post-closure Total System Performance Assessment. Although the parameters values defined in this analysis are intended for use in the GENII-S biosphere model and associated software, that model and software were not used directly in the development of this analysis.

The six parameters evaluated in this analysis are for two of the three exposure pathways to humans considered to calculate biosphere dose conversion factors: inhalation and external exposure. The inhalation pathway evaluates inhalation of respirable, resuspended dust from contaminated soils. Three parameters for this pathway were analyzed in this report.

1. **Mass Loading (g/m^3) —** Mass loading is the mass of suspended particles per volume of air. This parameter is used to calculate the concentration of radionuclides in the air resulting from resuspension of soil contaminated by irrigation. Mass loading was estimated in this analysis directly from measurements of particulate matter (≤10 :m in diameter) taken for the Yucca Mountain Site Characterization Project (YMP).

2. **Inhalation Exposure Time (hours/year) —** Inhalation exposure time is the amount of time a reference person inhales resuspended dust previously contaminated from irrigation water. This parameter is used by the GENII-S computer code (Leigh et al. 1993) to estimate the potential dose resulting from inhalation of radionuclides suspended in the air. To estimate inhalation exposure time, a time-activity budget was developed based on reasonable estimates of the behavior of people living in Amargosa Valley.

3. **Chronic Breathing Rate (m^3/day) —** Chronic breathing rate is the volume of air inhaled by a person per unit of time. This parameter is used to calculate the potential dose from inhaling contaminated dust particles. A literature review was conducted to identify the most appropriate value for this parameter.

The external exposure pathway evaluates potential radiation exposure from living and working in an environment (e.g., soil, vegetation) contaminated with radionuclides. External exposure is often referred to as groundshine. Three parameters for this pathway were analyzed in this report.

1. **Soil Exposure Time (hours/year) —** Soil exposure time is the amount of time a person spends outside in an area contaminated from groundwater irrigation. The time-activity budget developed for inhalation exposure time was used to estimate soil exposure time.

2. **Home Irrigation Rate(inches/year) —** Home irrigation rate is a measure of the amount of contaminated groundwater applied to the environment. This parameter is used to determine

the level of contamination of the soil in the calculation of potential dose resulting from groundshine. For this analysis, the irrigation requirements of locally grown turf grasses were calculated based on weather conditions in Amargosa Valley.

3. **Duration of Home Irrigation (months/year)** — Duration of home irrigation is the number of months during a year that groundwater is applied to the environment. This parameter is used to determine when a person may be exposed to soil that has been contaminated from groundwater irrigation. The irrigation requirements of locally grown turf grasses were considered to determine the value of this parameter.

Three estimates for each parameter were developed in this analysis. First, a distribution for each parameter was selected based on characteristics of the parameter or available data, and then reasonable, conservative estimates of the values were selected that define the distribution. Data distributions were selected from those that can be handled by the GENII-S computer code: fixed, normal, lognormal, triangular, uniform, loguniform, and empirical (Leigh et al. 1993, p. 5-33). Reasonable is defined as being reasonably expected to occur, based on (1) the characteristics of the critical group described in 10 CFR 63 regulations proposed by the Nuclear Regulatory Commission (NRC; 64 FR 8640-8678), (2) guidance from the Department of Energy (DOE) on the use of the proposed NRC regulations (Dyer 1999, p. 19 of Enclosure), and (3) information on the current population in Amargosa Valley (U.S. Census Bureau [USCB] 1990). Conservative is defined as a value or behavior that would result in a higher biosphere dose conversion factor. For example, watering a lawn for 12 months a year is considered more conservative than watering for fewer months because it would result in more frequent deposition of contaminated water and therefore a higher dose conversion factor. The second estimate for each parameter is a single, reasonably expected value to be used in a deterministic run of the GENII-S code, and was based on the type of distribution. The third estimate, to be used in an additional deterministic run of the GENII-S code, is a single, high bounding value that could occur based on extreme behaviors or conditions.

This analysis was conducted according to AP-3.10Q (Revision 2), *Analyses and Models*, and an approved development plan (CRWMS M&O 1999f). The only constraints, caveats, or limitations common to the entire analysis are those described above for reasonable/conservative and high bounding values.

All references cited in this document and listed in Section 8, other than those identified as inputs in Table 1, were included only to support or corroborate the assumptions, methods, and conclusion of the analyses and were not inputs required to produce the parameter values.

2. QUALITY ASSURANCE

The analyses in this AMR have been determined to be Quality Affecting in accordance with CRWMS M&O procedure QAP-2-0, *Conduct of Activities*, because the information will be used to support Performance Assessment and other quality-affecting activities. Therefore, this AMR is subject to the requirements of the *Quality Assurance Requirements and Description* (QARD) document (DOE 2000). This AMR is covered by the Activity Evaluation for *Scientific Investigation of Radiological Doses in the Biosphere* (CRWMS M&O 1999g).

Personnel performing work on this analysis were trained and qualified according to Office of Civilian Radioactive Waste Management (OCRWM) procedures AP-2.1Q, *Indoctrination and Training of Personnel*, and AP-2.2Q, *Establishment and Verification of Required Education and Experience of Personnel*. Preparation of this analysis did not require the classification of items in accordance with CRWMS M&O procedure QAP-2-3, *Classification of Permanent Items*. This analysis is not a field activity. Therefore, a *Determination of Importance Evaluation* in accordance with CRWMS M&O procedure NLP-2-0 was not required. The governing procedure for preparation of this AMR is OCRWM procedure AP-3.10Q, *Analyses and Models.*

3. COMPUTER SOFTWARE AND MODEL USAGE

No models or software were used or developed in this analysis. Although the parameters values defined in this analysis are intended for use in the GENII-S biosphere model and associated software, that model and software were not used directly in the development of this analysis.

4. INPUTS

The inputs for each parameter are described and justified below and summarized in Table 1. These inputs are the basis for parameter values used to model biosphere transport and uptake. Because biosphere transport and uptake are not considered principal factors (AP-3.15Q, *Managing Technical Product Inputs*, Attachment 6), qualified data inputs have been classified Qualified-Verification Level 2.

4.1 DATA

4.1.1 Mass Loading

Inhalable Particulate Matter (PM_{10}) (CRWMS M&O 1999b, parameter 1078). Twenty-four-hour measurements of particulate matter ≤10 :m (PM_{10}, :g/m^3) recorded at YMP Air Quality and Meteorological Monitoring Site 9 every six days from October 3, 1992 through December 30, 1997 were used to estimate this parameter. These data are summarized in CRWMS M&O (1999c, Table 2-3 on p. 13). Measurements of PM_{10} were used for this analysis instead of total suspended particulates because the Environmental Protection Agency (EPA) National Ambient Air Quality Standards for particulate matter require the measurement of PM_{10} (40 CFR 50.6, p. 7). In addition, PM_{10} values were chosen because these sized particles are inhalable and can be deposited in the respiratory tract (EPA 1994b, Figure 3-3 on p. 3-10). Airborne particles larger than 10 microns that may be deposited in the nasal pharyngeal and then swallowed are considered in the soil ingestion parameter of the ingestion pathway of GENII-S. Using PM_{10} data for mass loading will result in a conservative estimate of resuspended radioactive particulate matter because it is unlikely that all resuspended particles will be contaminated. Airborne particulate matter is generated over a large up-wind area, and some of these areas will not be contaminated by irrigation water.

Table 1. Summary of inputs used in this analysis. See Sections 4.1.1 through 4.1.6 for justification of the use of these inputs.

Analysis Parameter	Input	TDMS Parameter Name (and Number)	Data Tracking Numbers or Citation	Qualification Status
Data				
Mass Loading	Inhalable particulate matter (PM_{10})	Particle Characteristics (1078)	MO98PSDALOG111.000 TM000000000001.039 TM000000000001.041 TM000000000001.042 TM000000000001.043 TM000000000001.079 TM000000000001.082 TM000000000001.084 TM000000000001.096 TM000000000001.097 TM000000000001.098 TM000000000001.099 TM000000000001.105 TM000000000001.108	Qualified
Inhalation and Soil Exposure Times	Behavioral characteristics	Census Data (6923)	MO9911ANLMGRMD.003	Accepted
Chronic Breathing Rate	Breathing Rate	Chronic Breathing Rate (P6824)	MO0001SPACBR01.004	Accepted
Home Irrigation Rate	Average monthly temperature	Temperature (595)	MO9903CLIMATOL.001	Q-VL2[a]
Home Irrigation Rate	Average monthly solar radiation	Solar Flux (594)	MO9903CLIMATOL.001	Q-VL2[a]
Home Irrigation Rate	Average monthly precipitation	Precipitation Quantity (553)	MO9903CLIMATOL.001	Q-VL2[a]
Home Irrigation Rate	Crop coefficient (K_c):	Crop Coefficient (6952)	MO0001SPABCC01.002 MO0001SPATFC01.003	Accepted
Home Irrigation Duration	Duration of Irrigation	Duration of Home Irrigation (6827)	MO9911ANLMGRMD.000 MO9911ANLMGRMD.001	Accepted
Criteria				
All	Characteristics of the critical group	N/A	Dyer (1999, p. 19 of Enclosure);	N/A

[a] Qualified – Verification Level 2

These data were selected because there was a reasonably large number of measurements (315 24-hour measurements taken over 5 years) collected using well documented, industry accepted methods at the Yucca Mountain air quality monitoring site with conditions, including soils (CRWMS M&O 1999h, Figure 1 on p. 2), most representative of the Amargosa Valley farming community. Site 9 is the southernmost monitoring site at Yucca Mountain, located in the valley bottom at the northern end of the Amargosa Valley (CRWMS M&O 1999c, Figure 1-1 on p. 5

and Table 1-1 on p. 6). Site 9 generally has southerly winds during the day and northerly winds at night (CRWMS M&O 1999e, Figure 3-5 on p. 3-7). Methods used to collect PM_{10} data followed Nevada Work Instructions NWI-AQ-001, NWI-AQ-002, and NWI-AQ-016. The methods used to collect these data were based in part on 40 CFR 50, Appendix J (pp. 65 through 70), and EPA Quality Assurance Handbook for Ambient Air Quality Monitoring (EPA 1994a, Section 2.11). The methods are described in CRWMS M&O (1997, p. 4) and earlier reports. The sample size is large enough that uncommon events such as very high winds that cause temporal variation in mass loading likely were sampled.

4.1.2 Inhalation Exposure Time

Employment, occupational, and other behavioral characteristics of people living in Amargosa valley, determined during the 1990 census (USCB 1990; DTN: MO9911ANLMGRMD.003) were used to develop an assumption about the amount of time the critical group spends indoors and outdoors.

4.1.3 Chronic Breathing Rate

The recommended chronic breathing rate was derived from data in ICRP (1975, pp. 346 and 347; DTN: MO0001SPACBR01.004).

4.1.4 Soil Exposure Time

Same as Inhalation Exposure Time.

4.1.5 Home Irrigation Rate

1. **Average Monthly Temperature (°F)** (CRWMS M&O 1999a, parameter 595). Averages were calculated from five years (1993–1997) of data collected at YMP meteorological monitoring Site 9. This site is at an elevation of 838 m (2,750 feet) (CRWMS M&O 1999c, Table 1-1 on p. 6), near the southwest corner of the Nevada Test Site and 3.1 km north of the proposed location of the critical group at the intersection of U.S. Highway 95 and Nevada Route 373 (Dyer 1999, p. 19 of Enclosure).

   These data were selected because the data were collected under a YMP program that met the requirements of the QARD (DOE 2000) and because this is the southernmost Yucca Mountain meteorological site, located in the valley bottom at the northern end of the Amargosa Valley; thus it has conditions most representative of the Amargosa Valley farming community. The data are presented in CRWMS M&O (1999c, Table A-9 on p. A-10). For use in the Jensen-Haise equation (see Appendix A), temperatures were converted from the measured units of degrees celsius (°C) to degrees fahrenheit (°F) using the equation °F = (9/5 °C) + 32.

2. **Average Daily Incoming Solar Radiation Per Month (langleys/day)** (CRWMS M&O 1999a, parameter 594). Averages were calculated from five years of data collected at YMP Site 9. These data were selected because this weather station has conditions most representative of the farming community and the data were collected under a YMP program

that met the requirements of the QARD (DOE 2000). The data are presented in CRWMS M&O (1999c, Table A-9 on p. A-10). For the calculation of evapotranspiration (ET), the data were converted from the measured units of megajoules/m^2/day to langleys/day using the equation langleys/day = 23.89 (megajoules/m^2/day).

3. **Average Annual Precipitation** (CRWMS M&O 1999a, parameter 553). Averages were calculated from five years of data collected at YMP Site 9. These data were selected because they were collected under a YMP program that met the requirements of the QARD (DOE 2000) and the weather station has conditions most representative of the farming community. The data are presented in CRWMS M&O (1999c, Table A-9 on p. A-10).

4. **Crop Coefficient (K_c)** Monthly crop coefficients for bermudagrass (DTN: MO0001SPABCC01.002) and tall fescue (MO0001SPATFCO1.003) are as recommended by the Nevada Cooperative Extension for southern Nevada and are based on values reported in Devitt et al. (1992, Table 3 on p. 722; 1995b, Figure 2 on p. 56). These values are summarized in Table 3 in Section 6.4.

   Crop coefficient is an expression of the ET of a plant species relative to the potential ET of a reference species. Crop coefficients are commonly used in calculations of ET because field measurements of potential ET for an area only are needed for one reference crop (Martin et al. 1991a, p. 201).

   The crop coefficients for low maintenance bermudagrass and tall fescue were derived by the Nevada Cooperative Extension from studies of bermudagrass ET conducted in Las Vegas, Nevada (Devitt et al. 1992, Table 3 on p. 722; 1995b, Figure 2 on p. 56). These values were selected because they come from peer-reviewed, published studies conducted closer to Yucca Mountain than any other published values (e.g., Devitt et al. 1995a, Table 2 on p. 68). The studies were conducted using widely accepted methods for measuring ET by scientists that have experience using these methods.

   These coefficients were developed using a reference crop of cool-season grass, whereas the Jensen-Haise ET equation used in this analysis is for a reference crop of alfalfa. UCCE (1987, p. 6) state that "Several agencies and researchers have recommended using ET_o [i.e., from grass] directly as a method to estimate alfalfa ET_c [i.e., crop coefficient for alfalfa]." Conversely, Martin et al. (1991a, p. 202) state that grass usually uses 10-15% less water than alfalfa; thus, using a grass-based coefficient with an alfalfa-based estimate of ET may result in an 10-15% overestimate of water requirements. Therefore, this is an acceptable, conservative input for this analysis.

4.1.6 Duration of Home Irrigation

Estimates of the number of months that bermudagrass (MO9911ANLMGRMD.000) and tall fescue (MO9911ANLMGRMD.001) should be watered are based on recommendations from the Nevada Cooperative Extension (Morris and Johnson 1991, pp. 3 and 4; Morris and Van Dam 1989, pp. 3 and 4).

4.2 CRITERIA

Criteria regarding characteristics of the critical group will not be available until rules proposed by the NRC for 10 CFR 63, Section 115 (64 FR 8640-8678) are passed and incorporated into DOE requirements documents. DOE interim guidance (Dyer 1999, p. 19 of Enclosure) therefore were used to develop assumptions about the characteristics of the critical group.

4.3 CODES AND STANDARDS

None.

5. ASSUMPTIONS

5.1 Mass Loading

None.

5.2 Inhalation Exposure Time

Three assumptions about the behavior of members of the critical group were made for the analysis of inhalation exposure time (Section 6.2).

1. When in a contaminated area, the exposure rate experienced while indoors (including time spent inside vehicles) is half of that experienced while outdoors. This assumption is based on shielding factors recommended by the NRC (1977, p. 1.109-43). Because this shielding factor was developed by the regulatory agency responsible for licensing a repository at Yucca Mountain, this assumption does not need to be confirmed.

2. The average member of the critical group spends a certain amount of time each day outdoors tending a garden plot and doing other activities. Time spent outdoors by the average member of the critical group was assumed to be 827 hours/year (EPA 1997b, Table 15-120 on p. 15-136). This value is the amount of time "spent at home in the yard or other areas outside the home" based on survey data from 1301 adults, 18 years or older. The value of 827 hours/year is more conservative and more age-specific than 548 hours/year from a California study of 1,762 people 12 years of age or older (EPA 1997b, Table 15-7 on p. 15-25) or 450 hours/year from a nationwide survey of 2,762 people 12 years of age or older (EPA 1997b, Table 15-7 on p. 15-25). Therefore, 827 hours is a valid assumption of the time spent outdoors by adults and does not need to be confirmed.

3. Three lifestyle scenarios resulting in different inhalation exposure times were assumed to bound the distribution:

   - *Average*—The average member of the critical group is employed 35 hours/week, 50 weeks/year, in the vicinity of Yucca Mountain in a non-farming occupation. This is 1,750 hours/year (where one year equals 8,760 hours). This assumption is based on USCB (1990) census data. Commuting time to and from work is within the contaminated area and is assumed to be 5 minutes (0.083 hour) in each direction based on the second-most frequently reported travel time to work for the area (USCB 1990). The second most frequently reported time was selected because the most frequently reported time was much less conservative (40-44 minutes) and this statistic did not account for 7% of respondents that worked at home.

- *Least Exposed*—This person works indoors or outdoors the same number of hours as the average member of the group, and the work locality is in a non-contaminated area. Commuting time to and from work is considered to take place in a non-contaminated area. Commuting time was assumed to be 0.5 hour based on USCB (1990) data on the median (the value that divides a frequency distribution into two halves) travel time to work for the area. The least exposed person has a sedentary lifestyle and spends little time outdoors (25% of that determined for the average person).

- *Most Exposed*—This person works outdoors 60 hour/week (12 hours/day, 5 days/week; 3,120 hours/year) in a contaminated area (e.g., an irrigated agricultural area). Commuting time to and from work is within the contaminated area and is assumed to be 5 minutes (0.083 hour) in each direction based on the second-most frequently reported travel time to work for the area (USCB 1990). In addition, this person spends additional time outdoors tending a garden at home (the same amount as the average member of the group). This scenario is intended to be similar to the lifestyle of an agricultural worker, of which there are relatively few (< 3% of the population) in Amargosa Valley (USCB 1990).

These assumptions are based on DOE interim guidance (Dyer 1999, pp. 19 of Enclosure), census data from Amargosa Valley (USCB 1990), and reasonable estimates of the behavior of people in Amargosa Valley, and therefore do not need to be confirmed.

5.3 Chronic Breathing Rate

None.

5.4 Soil Exposure Time

The same assumptions about behaviors of the critical group developed for inhalation exposure time (Section 5.2) were made for the analysis of soil exposure time (Section 6.4).

5.5 Home Irrigation Rate

Two assumptions were developed for the analysis of irrigation rate (Section 6.5).

1. Deep percolation is the amount of water that passes below the root zone. In mesic regions, deep percolation can result from precipitation or irrigation in excess of ET that percolates beyond the root zone. In arid agricultural systems, deep percolation occurs intentionally during irrigation to leach salts (i.e., flush them below the root zone) that are deposited in the soil from irrigation water and that would decrease plant production. The most accurate way to measure deep percolation is to install underground lysimeters, which measure the amount

of water that moves below the root zone (e.g., Devitt et al. 1992, pp. 717 through 723). Review of published literature and discussions with University of Nevada Cooperative Extension personnel indicated that no lysimeter measurements have been performed in the agricultural areas surrounding Yucca Mountain.

In the absence of site specific data, a value of six inches was assumed for this analysis. This value was selected to be consistent with the value of percolation implied in the GENII-S code and to be compatible with other portions of that code (Napier et al. 1988, p. 4.58). The validity of this value for irrigation of tall fescue in Amargosa Valley, which is less salt-tolerant than bermudagrass (Martin et al. 1991a, Table 10-10 on p. 223), was checked using two equations, as shown in Appendix B. These equations use information on salt content of irrigation water and salt tolerance of plants to determine the amount of water required to leach salts. Values of 0.9 and 3.3 inches were calculated (Appendix B), which are substantially below the default value of 6 inches. Based on these calculations, deep percolation of 6 inches is considered a valid assumption for this analysis, and does not need to be confirmed

2. The high bounding value for irrigation rate is 25% higher than the maximum irrigation rate calculated for tall fescue. Irrigation rates higher than actual requirements would result from such factors as inefficient irrigation systems, intentional or unintentional over-irrigating, and higher leaching requirements on soils with high salt content. Although rates greater than 25% are possible, it is unlikely that someone would reach such an extreme because of the increased cost for pumping or buying groundwater and the detrimental effects that flooding would have on turfgrass and the rest of their landscape. The inputs and methods used to calculate maximum irrigation rate are conservative (e.g., use of high-maintenance turf grass crop coefficients) and result in an irrigation rate about 6% higher than that recommended for Las Vegas (see Section 6.5); thus, an increase of 25% above that maximum is a very conservative assumption that does not need further confirmation.

5.6 Duration of Home Irrigation

None.

6. ANALYSIS

6.1 MASS LOADING

One input, PM_{10} data from YMP Site 9 (Section 4.1.1), and no assumptions were used in the analysis of mass loading.

The reasonable, conservative distribution of mass loading was determined directly from the Site 9 PM_{10} data. Distributions that can be handled by the GENII-S computer code include fixed, normal, lognormal, triangular, uniform, loguniform, and empirical (Leigh et al. 1993, p. 5-33). The raw PM_{10} data were skewed toward low values (Figure 1) and a logarithmic transformation (log base 10) resulted in the best fit to the available distributions (Figure 2). Two zero values were removed from the data set prior to transformation because the logarithm of zero is an undefined value. Because the empirical distribution in GENII-S (which samples the data

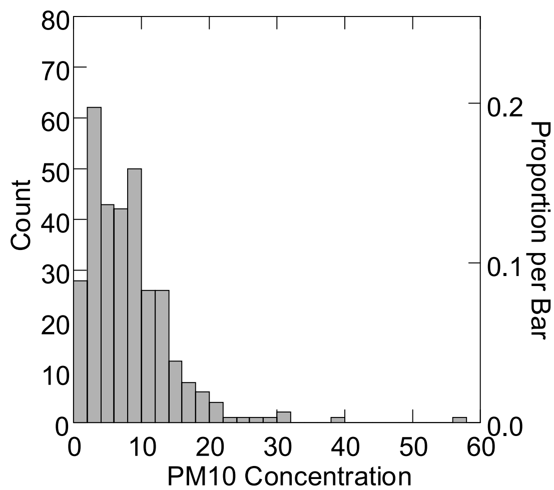

Figure 1. Untransformed PM_{10} concentration data (:g/m^3) from Site 9, 10/3/92 to 12/30/97 (CRWMS M&O 1999b).

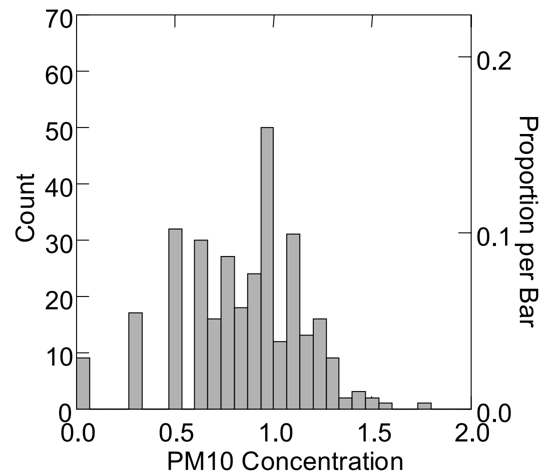

Figure 2. Log (base 10) transformed PM_{10} concentration data (:g/m^3) from Site 9, 10/3/92 to 12/30/97 (CRWMS M&O 1999b).

points to obtain a value each time during a run of the program) is restricted to only 100 data points (Leigh et al. 1993, p. 5-36) and the PM_{10} data set was much larger, lognormal was chosen as the best distribution for PM_{10} data.

GENII-S requires two values to define a lognormal distribution, the 0.1 (minimum) and 99.9th (maximum) percentiles. These percentiles were calculated using the mean and standard deviation of the log transformed data and the Z-distribution, using the equations:

$$Minimum = \mu - Z\sigma \text{ , and}$$

$$Maximum = \mu + Z\sigma \text{ ,}$$

where μ and σ are the mean (0.838) and standard deviation (0.313), respectively, of the log transformed PM_{10} data, and Z (3.09) is the value that describes the proportion of the normal curve that lies beyond a given normal deviate. These calculations resulted in a minimum log-transformed value of –0.1292 and a maximum log-transformed value of 1.805. Back calculating these values (i.e., taking the antilog) resulted in a minimum value of 0.743 :g/m^3 and a maximum value of 63.836 :g/m^3.

The mean of the non-transformed data, 8.725 :g/m^3, was selected as the reasonably expected estimate for a deterministic run.

The PM_{10} 99.9th percentile value described by the distribution (63.86 :g/m^3) was selected as the high bounding value because it is about 12% higher than the highest PM_{10} value (57 :g/m^3) recorded at Site 9.

PM_{10} data were recorded in : g/m^3 and converted to units of g/m^3 (values usable by GENII-S) by multiplying by 1.0×10^{-6}. The resulting estimates were a minimum of 7.4×10^{-7} g/m^3 and a maximum of 6.4×10^{-5} g/m^3. The reasonable expected value was 8.7×10^{-6} and the high bounding value was 6.4×10^{-5} g/m^3.

6.2 INHALATION EXPOSURE TIME

Based on the three assumptions listed in Section 5.2, a time activity budget was developed for the three lifestyle scenarios (Table 2). The inhalation exposure time category in Table 2 is the amount of time in hours per year that a member of the critical group is assumed to be exposed to, and will be inhaling, aerosolized radioactive material (i.e., dust). Inhalation exposure time (IET) is calculated using the equation:

$$IET = T_{OC} + \frac{T_{IC}}{2},$$

where T_{OC} equals the time spent outdoors in a contaminated area, and T_{IC} equals the number of hours spent indoors in a contaminated area. This equation is based on the assumption (#1 in Section 5.2) that the exposure rate indoors is one-half of that experienced outdoors.

The reasonable, conservative distribution of inhalation exposure time has a triangular probability function. The number of hours assumed to be spent outdoors by the most exposed individual is much higher than that of the average individual; therefore, symmetrical distributions (e.g., normal and uniform) are not valid. The triangular distribution was chosen because there is no information to indicate that more complex non-symmetrical distributions are more likely than the triangular distribution. This triangular distribution is described by a minimum value of 3,483.38 hours/year, the mode (referred to as best estimate in GENII-S, Leigh et al. 1993, p. 5-33) of 3,918.5 hours/year, and a maximum of 6,353.5 hours/year (Table 2). The reasonably expected value to use in a deterministic run of the GENII-S code is the mode of 3,918.5 hours/year.

The maximum estimate was also selected as the high bounding value. This maximum estimate was based on the lifestyle (i.e., outdoor worker such as a farmer working in the contaminated area) that will result in a high exposure rate relative to the average member of the critical group. The number of hours that this worker is assumed to spend outdoors (working 60 hours/week for 52 weeks, plus 827 additional hours spent outdoors, totaling 3,947 hours/year) is higher than the values from two other recent studies. The NRC, in their Iterative Performance Assessment Phase 2 (NRC 1995, p. 7-10), used a lower value by assuming that farmers spent only 27% of their time outdoors (6.48 hours/day or 2,336 hours/year), resulting in an inhalation exposure time of 5,548 hours/year. In addition, LaPlante and Poor (1997, p. 2-23) assumed that time spent out doors for a "resident farmer" who was employed outside of the contaminated area (2,080 hours/year) would equal 100 hours/year in a garden and 1,700 additional hours outdoors. This scenario results in an inhalation exposure time of 4,200 hours/year (LaPlante and Poor 1997, p. 2-23).

6.3 CHRONIC BREATHING RATE

Estimates of chronic breathing rates were selected based on a literature review of the breathing rates of adults. Only adults were considered because DOE interim guidance (Dyer 1999, p. 19 of Enclosure) and proposed NRC guidelines (64 FR 8677) state that the average member of the critical group is an adult.

Several breathing rates have been used to assess exposure to airborne contaminants (reviewed in EPA 1997a, pp. 5-1 through 5-27). The following are examples of the range of values previously used and include the estimates chosen for the chronic breathing rate parameter.

- The EPA *Exposure Factors Handbook* recommends a value of 15.2 m^3/day for an adult male, 19 to 65 years of age (reviewed in EPA 1997a, p. 5-24). However, EPA (1997a, p. 5-1) states that a value of 20 m^3/day is used as the default value for the EPA *Integrated Risk Information System*.

- The International Commission on Radiological Protection (ICRP), Publication 23 (ICRP 1975, p. 346), uses a value of 23 m^3/day for a 70-kg adult male. This value is based on eight hours each of resting, light activity work, and nonoccupational activity.

- ICRP (1975, p. 346) also identifies a value of 31 m^3/day (i.e., 35% more than the 23 m^3/day for an average lifestyle) for a 70-kg adult male that is engaged in more strenuous activities.

- Based on the information in ICRP (1975, pp. 346 and 347), an adult male engaging in

Table 2. Time (hours/year) spent in contaminated and uncontaminated areas based on three lifestyle scenarios.

		Contaminated Areas		Non-contaminated Areas	
Scenario	**Activity**	**Outdoors**	**Indoors**	**Outdoors plus Indoors**	**Inhalation Exposure Time[a]**
Least Exposed	At work	0.00	0.00	1750.00	
	Commuting	0.00	0.00	250.00	
	At home	206.75	6553.25	0.00	
	Total	206.75	6553.25	2000.00	3483.38
Average	At work	0.00	0.00	1750.00	
	Commuting	0.00	41.50	0.00	
	At home	827.00	6141.50	0.00	
	Total	827.00	6183.00	1750.00	3918.50
Most Exposed	At work	3120.00	0.00	0.00	
	Commuting	0.00	43.00	0.00	
	At home	827.00	4770.00	0.00	
	Total	3947.00	4813.00	0.00	6353.50

[a] Calculated as 100% of time spent outdoors in a contaminated area plus 50% of time spent indoors in a contaminated area (NRC 1977, p. 1.109-43).

moderate to heavy activity for 16 hours/day and resting for 8 hours/day would consume approximately 42 m^3/day.

Chronic breathing rate was considered to have a fixed distribution because the GENII-S code treats this input as a fixed value. The ICRP value of 23 m^3/day was selected as the reasonable, conservative estimate and as the reasonably expected value to use in a deterministic run of GENII-S. This value was selected primarily because it is based on a scenario that matches the behavioral characteristics of the reference group as proposed by the NRC (64 FR 8640-8678). In addition, ICRP (1975) is considered the international standard for physical and physiological characteristics of "reference man."

The ICRP value of 31 m^3/day was selected as the high bounding value because it matches a likely scenario for a person in Amargosa Valley working outdoors in an agricultural setting. The high value of 42 m^3/day was considered unreasonable because it is doubtful that a person could sustain the level of activity required to maintain this high breathing rate.

These recommended values from ICRP (1975) have been classified as accepted (DTN: MO0001SPACBR01.004).

6.4 SOIL EXPOSURE TIME

The assumptions, scenarios, and much of the analyses for determining soil exposure time are the same as those for determining inhalation exposure time (see Section 6.2), and are not repeated here. The only difference between these parameters is that inhalation exposure time includes time spent indoors in a contaminated environment; soil exposure time does not. Thus, the values presented in Table 2 for time spent outdoors in a contaminated environment are equal to the soil exposure time.

Based on the information presented in Section 6.2, the reasonable, conservative distribution of soil exposure time is triangular with a minimum estimate of 206.75 hours/year, the mode (referred to as best estimate in GENII-S, Leigh et al. 1993, p. 5-33) of 827.0 hours/year, and maximum estimate of 3,947.0 hours/year. The reasonably expected value to use in a deterministic run of GENII-S is the mode of 827.0 hours/year. The high bounding value is the maximum value of 3,947.0 hours/year.

6.5 HOME IRRIGATION RATE

The irrigation rate of turfgrass was calculated for this analysis. Turf was chosen because lawns are common in southern Nevada, turf requires year-round irrigation in this region, and turf has a high water requirement relative to garden crops and ornamental plants; thus, it will result in a realistic and conservative estimate of home irrigation rate. The data listed in Section 4.1.5 were used as inputs for temperature, solar radiation, precipitation, and crop coefficients. Assumptions were developed for deep percolation and the high bounding value (Section 5.5).

Irrigation rate of turfgrass is influenced by the type of grass grown and the maintenance regime followed (Devitt et al. 1992, pp. 717 through 723). Two combinations of turf and maintenance regimes were analyzed to obtain a range of home irrigation rates. For a low estimate, irrigation rate was calculated for warm-season bermudagrass overseeded with perennial ryegrass during winter and grown in a low-maintenance (e.g., low rate of fertilizer application, low mowing frequency, high mowing height) park setting, as described by Devitt et al. (1992, pp. 717 through 723). For a high estimate, irrigation rate was calculated for cool-season tall fescue grass grown under a relatively high-maintenance regime as described by Devitt et al. (1995b, pp. 47 through 63).

Irrigation requirements for low-maintenance bermudagrass and high-maintenance tall fescue represent a reasonable, conservative range of irrigation rates for turfgrass in southern Nevada. Bermudagrass is a commonly used, drought adapted turfgrass in southern Nevada (Morris and Johnson 1991, p. 1). Although maintenance regimes resulting in lower irrigation rates often are used in southern Nevada (e.g., no winter overseeding or irrigation, and allowing grass to die back during mid-summer), the park-based maintenance regime used in this analysis will result in a higher, more conservative estimate. The irrigation rate of tall fescue is suitable for the high estimate because cool season grasses are not as well adapted to arid climates as warm-season grasses and require about 20-30% more irrigation water (Morris and Johnson 1986, pp. 1 through 3; Undated B, p. 1), and because tall fescue is the recommended cool season grass for southern Nevada (Morris and Johnson, 1986, p. 3).

Irrigation rate (IR, inches/year) was calculated using the equation:

$$IR = \sum_{m=1}^{12} ET_m - P + DP,$$

where m = month, ET_m = total monthly ET, P = annual precipitation, and DP = annual deep percolation. This equation is a reduction of the soil water balance equation in Martin et al. (1991a, p. 200), based on a steady-state condition (i.e., soil water at the beginning of the year equals that at the end of the year). This equation accounts for the water needs of the plant being irrigated (transpiration) and the major site-specific inputs (precipitation and deep percolation) and outputs (evaporation) of water.

Evapotranspiration for a plant species typically is calculated based on the ET for a reference crop (i.e., reference ET) at the location of interest multiplied by a coefficient specific to the species being considered (Martin et al. 1991a, pp. 201 through 204; UCCE 1987, pp. 1 through 12). For this analysis, reference ET was calculated using the Jensen-Haise equation (Martin et al. 1991b, p. 334), as described and justified in Appendix A and summarized in Table 3.

Monthly ET was calculated by multiplying reference ET by the monthly crop coefficients for bermudagrass (Devitt et al. 1992, Table 3 on p. 722) and tall fescue (Devitt et al. 1995b, Figure 2, on p. 56). Monthly ET for bermudagrass ranged from 0.84 inches in December and January to 8.26 inches in July and totaled 49.2 inches annually (Table 3). Actual annual ET of low-maintenance bermudagrass in Las Vegas has been measured at 42 inches (Devitt et al. 1992, p. 720). Monthly ET for tall fescue ranged from 0.65 inches in December to 15.32 inches in July, and totaled 84.5 inches annually (Table 3). Actual annual ET of tall fescue in Las Vegas has been measured at 87 inches (Devitt et al. 1995b, p. 59).

Using values of 3.59 inches annual precipitation (based on data described in Section 4.1.5 #3) and 6 inches deep percolation (Section 5.5 #1), the minimum irrigation rate (inches/year), based on the requirements of low-maintenance bermudagrass, is

$$IR = \sum_{m=1}^{12} ET_m - P + DP = 49.2 - 3.6 + 6 = 51.6\,.$$

This value is slightly lower that the estimate of about 60 inches/year for the Las Vegas Valley (Morris and Johnson 1991, p. 3). It is also lower than the rate of 74 inches/year recommended for bermudagrass by the Las Vegas Valley Water District (Undated, pp. 10 and 11). It is expected that these published estimates are somewhat higher than the estimate calculated for this analysis because the published estimates are based on a high-maintenance regime. They also use a higher deep percolation rate (15% of annual irrigation = 9 or 13 inches, respectively) because of the high salinity of the Colorado River water used in Las Vegas (Las Vegas Valley Water District Undated, pp. 10 and 11). Thus, a rounded estimate of 52 inches/year based on site-specific information is a valid estimate of the minimum irrigation rate used by a member of the critical group.

The maximum irrigation rate (inches/year), based on the requirements of tall fescue, is

$$\mathrm{IR} = \sum_{\mathrm{m}=1}^{12} \mathrm{ET_m} - \mathrm{P} + \mathrm{DP} = 94.4 - 3.6 + 6 = 96.8\,.$$

This value is slightly higher than 91 inches/year recommended for tall fescue by the Las Vegas Valley Water District (Undated, pp. 12 and 13). Thus, 97 inches/year is a conservative estimate of the maximum irrigation rate used by a member of the critical group.

The reasonable, conservative distribution of home irrigation rate has a uniform probability function. The actual rate at which turfgrass is irrigated is dependent upon numerous decisions made by the residents, such as fertilization rates, frequency of mowing, and the efficiency of irrigation equipment. These choices are dependent upon the quality of grass residents desire and the amount of effort and money they are willing to expend on maintaining their lawn. Because the range of these choices is based on personal preference, and all choices are equally likely, a uniform distribution was selected.

Based on this analysis, the reasonable, conservative distribution of home irrigation rate has a uniform probability distribution with a minimum of 52 inches/year and a maximum of 97 inches/year. The reasonably expected value to be used in a deterministic run of GENII-S is 74.5 inches/year, the midpoint between the minimum and maximum values. Based on Assumption 2 in Section 5.5, the high bounding value is 121 inches/year (25% greater than the maximum of the distribution).

6.6 DURATION OF HOME IRRIGATION

For the reasons described in the analysis of home irrigation rate (Section 6.5), the irrigation requirements of turfgrass were considered in this analysis. A literature review was conducted to determine the irrigation requirements of turfgrass species.

Table 3. Average monthly temperature and solar radiation at YMP Site 9, monthly reference evapotranspiration (ET_r), and monthly crop coefficients and evapotranspiration for bermudagrass and tall fescue. Values presented are rounded. Calculations were done using more precise values from the original data sources.

	Average Monthly Temperature		Average Daily Solar Radiation			Crop Coefficient		Evapotranspiration (inches)[g]	
Month	**°C**[a]	**°F**[b]	**mj/m^2/day**[a]	**langleys/day**[c]	**ET_r (inches)**[d]	**Bermudagrass**[e]	**Tall Fescue**[f]	**Bermudagrass**	**Tall Fescue**
January	7.1	44.8	9.5	227.0	2.04	0.41	0.95	0.84	1.94
February	9.6	49.3	13.9	332.1	3.09	0.41	0.95	1.27	2.94
March	13.6	56.5	19.4	463.5	5.73	0.41	0.95	2.35	5.45
April	16.7	62.1	24.6	587.7	7.95	0.55	0.95	4.37	7.55
May	22.1	71.8	27.5	657.0	11.02	0.55	0.95	6.06	10.47
June	27.4	81.3	29.9	714.3	13.49	0.55	1.1	7.42	14.84
July	31.0	87.8	29.4	702.4	15.02	0.55	1.1	8.26	16.52
August	30.5	86.9	27.0	645.0	13.63	0.55	1.1	7.49	14.99
September	25.4	77.7	22.6	539.9	9.66	0.55	0.95	5.31	9.18
October	17.7	63.9	17.4	415.7	6.03	0.55	0.95	3.31	5.73
November	10.6	51.1	11.9	284.3	2.98	0.55	0.95	1.64	2.83
December	6.9	44.4	9.6	229.3	2.04	0.41	0.95	0.84	1.94
Annual Sum					**92.69**			**49.17**	**94.37**

[a] CRWMS M&O 1999a.

[b] Converted as (9/5)°C+32.

[c] Converted as langleys/day = 23.89(megajoules/m^2/day).

[d] See Appendix A for details about the calculation of reference evapotranspiration.

[e] DTN: MO0001SPABCC01.002

[f] DTN: MO0001SPATFC01.003

[g] Evapotranspiration = $ET_r \times$ crop coefficient.

Table 4. Summary of parameter values for GENII-S code input derived from analyses presented in this report.

Pathway Parameter	Distribution	Reasonably Expected Value[a]	High Bounding Value[a]
Exposure from Inhalation			
Mass Loading (grams/m^3)	Lognormal: 0.1 percentile = 7.4×10^{-7}, 99.9 percentile = 6.4×10^{-5}	8.7×10^{-6}	6.4×10^{-5}
Inhalation Exposure Time (hours/year)	Triangular: min = 3,483.38, mode[b] = 3,918.5, max = 6,353.5	3,918.5	6,353.5
Chronic Breathing Rate (m^3/day)	Fixed: 23	23	31
External Ground Exposure			
Soil Exposure Time (hours/year)	Triangular: min = 206.75, mode[b] = 827, max = 3,947	827	3,947
Home Irrigation Rate (inches/year)	Uniform: min = 52, max = 97	74.5	121
Duration of Home Irrigation (months/year)	Fixed: 12	12	12

DTN: MO0003SPAIPV01.005 (CRWMS M&O 2000)

[a] Input values to be used in a deterministic run of the computer code, GENII-S.
[b] Mode is referred to as best estimate in GENII-S (Leigh et al. 1993, p. 5-33).

The Las Vegas Valley Water District (Undated, pp. 10 through 13) and the University of Nevada Cooperative Extension (Morris and Johnson 1991, pp. 3 and 4; Morris and Van Dam 1989, pp. 3 and 4) recommend that cool and warm season grasses be irrigated throughout the year in southern Nevada.

Based on these recommendations, the reasonable, conservative distribution is a fixed value of 12 months. The reasonably expected and high bounding values to be used in deterministic runs of GENII-S also are the maximum possible value of 12 months.

These recommended values from Nevada Cooperative Extension have been classified as accepted (DTN: MO9911ANLMGRMD.000 and MO9911ANLMGRMD.001).

7. CONCLUSIONS

This analysis report documents the selection of the recommended reasonable, conservative distribution; reasonably expected value; and high bounding value for six parameters needed to calculate biosphere dose conversion factors (Table 4).

The primary uncertainty associated with these recommendations is the definition and characteristics of the critical group, which are defined in DOE guidance (Dyer 1999, p. 19 of Enclosure). These characteristics are based on rules proposed by the NRC for 10 CFR 63 (64 FR 8640–8678). If the final NRC rules differ from the proposed rules enough to cause changes in DOE guidance, revision of this analysis will have to be considered.

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8.3 CODES, STANDARDS, AND REGULATIONS

40 CFR 50. Protection of Environment. National Primary and Secondary Ambient Air Quality Standards.

64 FR 8640-8678 (1999). Disposal of High-Level Radioactive Wastes in a Proposed Geologic Repository at Yucca Mountain, Nevada.

8.4 PROCEDURES

AP-2.1Q, REV 0 ICN 0, *Indoctrination and Training of Personnel*

AP-2.2Q, REV 0 ICN 0, *Establishment and Verification of Required Education and Experience of Personnel*

AP-3.10Q, REV 2 ICN 0, *Analyses and Models*

AP-3.15Q, REV 1 ICN 1, *Managing Technical Product Inputs*

AP-SI.1Q, REV 2 ICN 4, *Software Management*

AP-SIII.2Q, REV 0 ICN 2, *Qualification of Unqualified Data and the Documentation of Rationale for Accepted Data*

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QAP-2-0, REV 2 ICN 0, *Conduct of Activities*

QAP-2-3, REV 10 ICN 0, *Classification of Permanent Items*

APPENDIX A

CALCULATION OF REFERENCE EVAPOTRANSPIRATION (ET_R) AND JUSTIFICATION OF THE SELECTED EQUATION.

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Calculation

Monthly reference evapotranspiration was calculated using the Jensen-Haise equation (Martin et al. 1991b, p. 334):

$$ET_r = \frac{C_T(T - T_x)R_s}{1486} \text{days}$$

where:

$C_T = 1/(C_1 + C_2C_H) = 1/\{58.10 + 13(1.11)\} = 0.014$

$C_1 = 68 – 3.6$(elevation in feet)$/1{,}000 = 68 – 3.6(2{,}750)/1{,}000 = 58.10$

$C_2 = 13$, °F (a constant)

$C_H = 50/(e_2 – e_1)$, mbars $= 50/(70.74 – 25.63) = 1.11$

$T_x = 27.5 – 0.25(e_2 – e_1) –$ elevation$/1{,}000 = 27.5 – 0.25(70.74 – 25.63) – 2{,}750/1{,}000 = 13.47$

e_2 = saturated vapor pressure (mbars) at the mean maximum air temperature for the hottest month (39.2°C; CRWMS M&O 1999a; CRWMS M&O 1999c, Table A-9 on p. A-10). Calculated using the following equation from Buck (1982, p. 1532):

$$e_s = 6.1121\left\{\exp\left(\frac{17.502(°C)}{(240.97 + °C}\right)\right\} = 6.1121\{\exp(2.45)\} = 70.74$$

e_1 = Saturated vapor pressure (mbars) at the mean minimum air temperature for the hottest month (21.5°C; CRWMS M&O 1999a; CRWMS M&O 1999c, Table A-9 on p. A-10). Calculated using the following equation from Buck (1982, p. 1532):

$$e_s = 6.1121\left\{\exp\left(\frac{17.502(°C)}{(240.97 + °C}\right)\right\} = 6.1121\{\exp(1.43)\} = 25.63$$

R_s = Incoming solar radiation, langleys/day (See Table 3)

T = Average monthly air temperature, °F (See Table 3)

days = number of days per month

Example: (average monthly temperature and solar radiation are from Table 3)

January ET_r (inches) =

$$ET_r = \frac{0.014(44.8 - 13.47)227}{1486} 31 = 2.04.$$

Justification of Jensen-Haise Equation:

The Jensen-Haise equation was chosen for the calculation of reference ET because it is relatively simple to use and is generally reliable for calculating ET over long periods (e.g., weekly) in arid climates using the type of climate data available for the Amargosa Valley region (Martin et al. 1991b, p. 334). This equation accounts for local temperature and solar radiation. However, it does not incorporate the effects of wind, as do more complicated methods such as the modified Penman equation (Martin et al. 1991b, pp. 334 through 336). Devitt et al. (1995a, pp. 75 through 81) demonstrated that high wind runs can influence calculations of ET in the southwestern United States.

To ensure that the Jensen-Haise equation did not underestimate reference ET, the results calculated for this analysis (Table 3) were compared to two unpublished estimates of ET for southern Nevada that used the modified-Penman equation (Figure A-1). The first was calculated from nine years (1986–1994) of climate data from Pahrump, Nevada (Contact Report; S.L. LeStrange to G.D. McCurdy, Western Regional Climate Center, Reno Nevada; including computer code, weather data, and results of equation; ACC: MOL.19990323.0175). The second was based on four years of data (1988, 1990–1992) from Las Vegas (Fax transmission, R.L. Morris, University of Nevada, Reno, Cooperative Extension, to S. LeStrange; July 28, 1997; ACC: MOL.19990629.0319). High and low estimates were considered for Las Vegas.

The Jensen-Haise equation resulted in values that were about 1 inch lower than the modified-Penman estimates during November–January, but as much as 4 inches higher during June–August (Figure A-1). Annual reference ET calculated for the proposed location of the critical group (92.7 inches, Table 3) was higher than that calculated for Pahrump (84.8 inches) and near the high end of the range of values calculated for Las Vegas (84.1–96.7 inches). It is expected that ET for the proposed location of the critical group would be slightly lower than the maximum for Las Vegas because the weather data used to calculate ET at that site (838 m; CRWMS M&O 1999c, Table 1-1 on p. 6) came from a site about 180 m higher than the elevation in Las Vegas (659 m; Devitt et al. 1995a, Table 1 on p. 68). The monthly ET values calculated for the proposed location of the critical group using the Jensen-Haise equation also are within the range or higher than those reported for other locations in the southwestern U.S. (Devitt et al. 1992, Table 2 on p. 719; UCCE 1987, Figure 1 on p. 3; Devitt et al. 1995a, Figure 3 on p. 77). Therefore, the results of the Jensen-Haise equation used in this analysis are valid, conservative estimates of monthly reference ET.

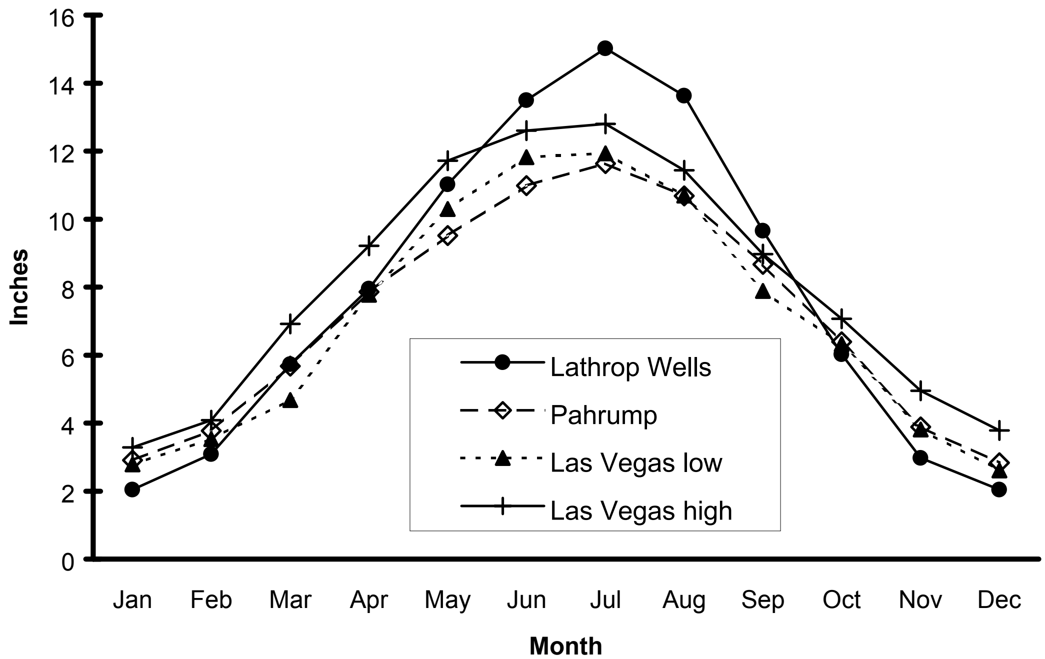

Figure A-1. Reference evapotranspiration (in inches) estimated at the proposed location of the critical group (labeled as "Lathrop Wells" in this figure) and measured in Pahrump (Contact Report; S.L. LeStrange to G.D. McCurdy, Western Regional Climate Center, Reno Nevada; including computer code, weather data, and results of equation. ACC: MOL.19990323.0175) and Las Vegas. (Fax transmission, R.L. Morris, University of Nevada, Reno, Cooperative Extension, to S. LeStrange; July 28, 1997; ACC: MOL.19990629.0319).

APPENDIX B

CONFIRMATION OF A DEEP PERCOLATION VALUE

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Two equations were used to confirm the validity of a default deep percolation value of 6 inches. These equations use the same data on salt tolerance of crops, but use different methods to determine the leaching requirement (LR), which is the minimum fraction of the total applied water that must pass through the root zone to prevent a reduction in crop yield due to salt accumulation. These calculations were done only for tall fescue, which is less salt tolerant than bermudagrass (Martin et al. 1991a, Table 10-10 on p. 223), and therefore requires a higher level of percolation.

Equation 1. Martin et al. (1991a, pp. 224 through 226) present a method for approximating LR and using an iterative calculation to determine the total annual irrigation depth required to maintain an appropriate salt balance. Iteration is required because one of the inputs, irrigation depth, is not known. Known values for this equation are:

ET_c = evapotranspiration for tall fescue = 85 inches (Table 3)

P = Precipitation = 3.6 inches (CRWMS M&O 1999a, parameter 553).

EC_i = Electrical conductivity of irrigation water = 0.51 dS/m. Calculated as the average conductivity of water from 31 irrigation or domestic wells (Table B-1) located in the village of Amargosa Valley (formerly Lathrop Wells) or west of State Route 373 and south of Highway 95 in Amargosa Valley (McKinley et al. 1991, pp. 9 through 17). These data are skewed somewhat toward low values; only 9 of the 31 measurements are above the mean. These nine wells are at least 9 km from the intersection of State Route 373 and U.S. Highway 95 and the eight most saline wells are more than 16 km south or southwest of that intersection. These most saline wells are located near the Nevada-California border where the water table is much shallower. Thus, the mean of 0.51dS/m is a reasonable conservative (i.e., high) estimate of salinity expected within the region being evaluated for the reference group.

EC_t = electrical conductivity at salt tolerance threshold = 3.9 dS/m (Martin et al. 1991a, Table 10-10 on p. 223). This is the salinity of irrigation water at which the productivity of tall fescue begins to be affected.

Determination of deep percolation requires the following steps:

1. Calculate the ratio of the electrical conductivity at the salt tolerance threshold to the electrical conductivity of irrigation water: EC_t:EC_i = 3.9 dS/m) 0.51 dS/m = 7.65

2. Determine the LR using Figure 10-13 of Martin et al. (1991a, p. 225) . 0.05 (Figure 10-13 shows L_r reaching a lower asymptote of about 0.05 at ratios greater than about 3.5).

3. Calculate annual depth (in inches) of irrigation water (I_i) required to prevent a decrease in production:

$$I_i = \frac{ET_c}{1 - L_r} - P = \frac{85}{1 - 0.05} - 3.6 = 85.9,$$

4. Calculate the electrical conductivity of applied water (EC_w) (i.e., diluted by rainfall):

$$EC_w = \frac{EC_i I_i}{I_i + R_i} = \frac{0.51(85.9)}{85.9 + 3.6} = 0.49\ .$$

5. Determine a new LR based on the ratio of electrical conductivity at the salt tolerance threshold to the electrical conductivity of applied water: EC_t:EC_w (3.9/0.49 = 7.96). From Figure 10-13 of McKinley et al. (1991), LR . 0.05.

6. If necessary, recalculate I_i based on the new LR. Because LR does not change at such high ratios, this step and additional iteration is not necessary. Annual depth of irrigation water required to prevent a decrease in production is 85.9 inches.

Thus, the amount of water required for deep percolation in addition to the 85 inches needed for evapotranspiration is 0.9 inches (85.9 – $ET_{c.}$).

Equation 2. Donahue et al. (1997, pp. 271 through 273) present an equation for LR that is based on the amount of water needed for leaching salts that is in addition to that needed to wet the root zone. For this equation to be used with the data available, one must assume that irrigation is sufficiently applied so that the entire root zone is wetted. Although this assumption may not always be met, completely wetting the root zone is the most efficient method for irrigating; thus, it is valid to assume that this assumption usually will be met.

This equation requires two inputs.

EC_i = Electrical conductivity of irrigation water = 0.51 dS/m (Table B-1).

EC_{dw} = Electrical conductivity causing a 50 percent decrease in yield = 13.33 dS/m. Calculated as yield reduction threshold + (50/yield reduction per unit of salinity increase) = 3.9 dS/m + (50)5.3 dS/m) = 13.3 dS/m. Yield reduction values for tall fescue are from Table 10-10 of Martin et al. (1991a, p. 223).

LR is calculated as:

$$\mathrm{LR} = \frac{\mathrm{EC_i}}{\mathrm{EC_{dw}}} = \frac{0.51\mathrm{dS/m}}{13.33\mathrm{dS/m}} = 0.038$$

This value is similar to that approximated above using Martin et al (1991a, Figure 10-10).

The LR is then multiplied by the total amount of water applied via irrigation (0.038 × 85 inches) to obtain a deep percolation value of 3.3 inches.

This value is slightly higher than that obtained above using the equation of Martin et al. (1991a, pp. 224 through 226) because Martin et al. (1991a, pp. 224 through 226) account for the addition of salt-free precipitation (in step 3). However, both values are substantially below the default value of 6 inches. Thus, 6 inches is a valid assumption for this analysis.

Table B-1. Electrical conductivity of 31 wells in Amargosa Valley located in the village of Amargosa Valley (formerly Lathrop Wells) or south and west of the intersection of U.S. Highway 95 and State Route 373 (McKinley et al. 1991, pp. 9 through 17).

Site Number	Distance (km)[a]	Electrical Conductivity (dS/m)[b]
37	0.09	0.49
34	3.59	0.34
35	4.33	0.33
36	4.87	0.34
63	9.01	0.65
57	9.13	0.30
60	9.73	0.43
58	9.79	0.31
61	9.84	0.37
59	10.18	0.32
65	12.95	0.30
66	13.36	0.31
53	13.86	0.32
54	15.10	0.33
44	15.44	0.34
43	15.96	0.37
51	16.04	0.35
55	16.33	0.34
77	16.77	0.80
76	17.17	0.38
73	17.87	0.31
56	18.03	0.83
47	18.54	1.07
75	18.73	0.29
42	18.74	0.95
78	18.88	0.28
74	18.90	0.35
39	20.04	0.98
72	20.27	1.29
40	20.71	0.96
89	25.60	0.70
Average		0.51

[a] Distance from the intersection of U.S. Highway 95 and State Route 373 to the well.

[b] Converted from µS/cm (units used by McKinley et al. 1991, pp. 14 through 17) to dS/m using the equation dS/m = 0.001(µS/cm).